Development of a Working Template for Crosscutting Technologies

John Coates
Coates Consulting
Consultant to DoE/OIT

Sensor & Controls

Summary

- The most efficient approach to developing a technology is to make it crosscutting
- Crosscutting means that a technology used in one industry segment has useful application(s) in other industry segments
- A review of current funded projects has indicated that most projects do not provide crosscutting technologies as the end product
- Most projects provide technologies that are too focused to an individual application or industry
- It would be cost-prohibitive to make most current technology projects truly crosscutting

Introduction: The Need for a Working template

- Most projects involve a very rigid development program where the technology is developed solely for the end application
- Extraction of the core technology from a project is often cost-prohibitive
- In future projects the technologies must ideally be separable from the target application
- In a project proposal the investigator must outline how the project technologies may be applied beyond the target application

Current Situation

- Most current OIT projects have been initiated via one of two routes:
  - Development of a new technology to fit a defined industrial need or application
  - Making an existing technology fit an industrial application (sometimes a technology looking for an application)
- The technology under development is customized and tailored to the end application
- It is understood that sometimes the economics of a project forces the customization
- Focus of current presentation will be primarily on sensor technologies

Solicitation Guidelines for Sensors and Controls Needs…a Reminder

- Sensor & Measurement Technologies
  - Self-diagnostics and self-calibration
  - Harsh environment sensing
  - Non-contact sensing
  - Miniaturization
  - High-speed accurate measurements
  - Low cost
  - Reliability
- Data Processing & Transformation
- Sensor & Control Integration

Review of Existing Projects

- Current OIT projects reviewed are separated into two classes:
  - Sensors & Controls projects
  - Industries of the Future (IOF) projects that involve sensors or measurement devices
- Sensor & controls projects
  - Most are highly focused
  - A few are true sensor projects
  - Most involve customized systems
- Industries of the Future (IOF) projects
  - Most are highly focused…systems focused
  - A few use technologies that have crosscutting potential
  - Most involve instrumentation rather than “sensor” technologies (instruments tend to be more expensive)

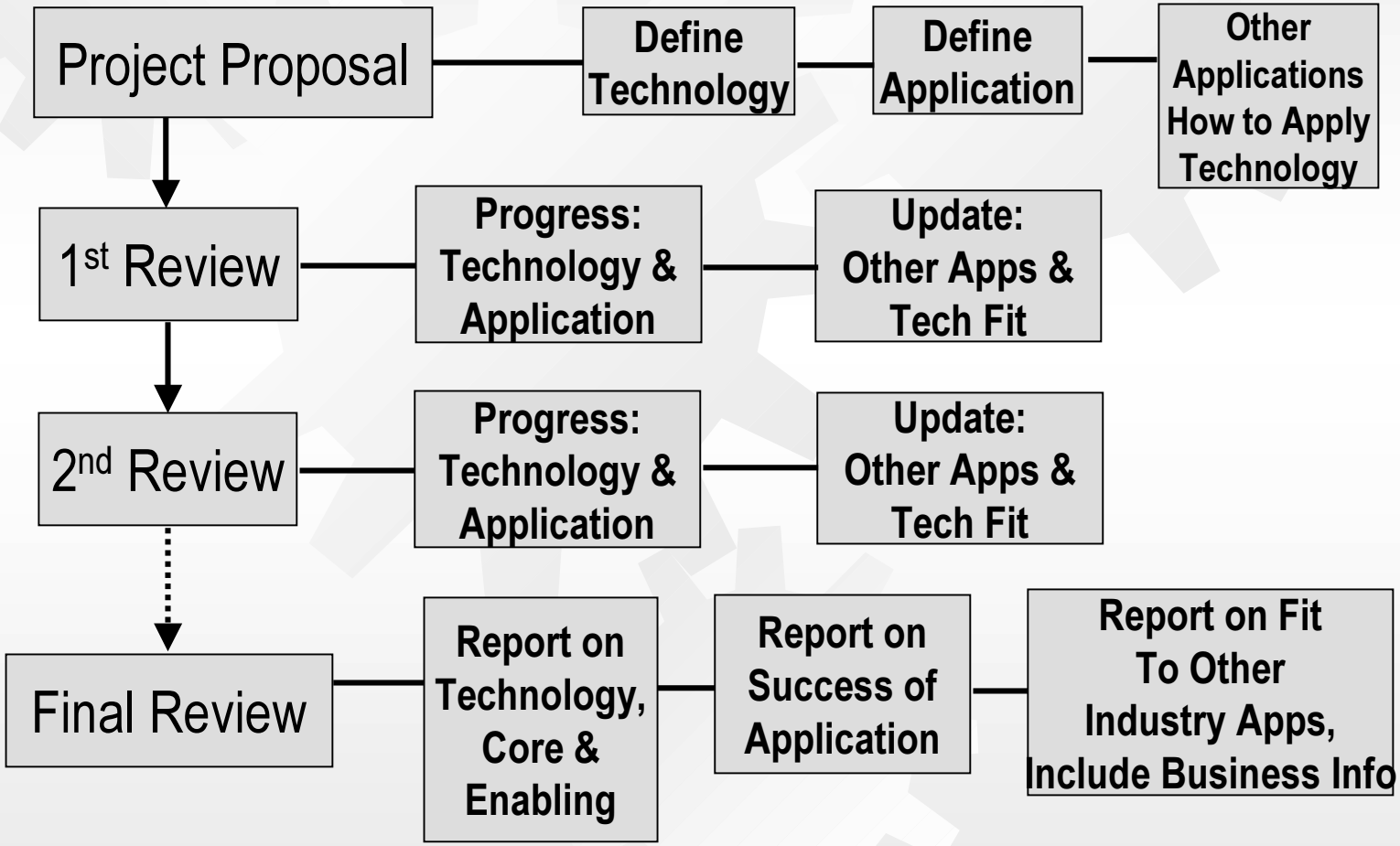
Outline of Template

1. Summary of project
2. Define core and enabling technologies
3. Indicate Applications of Technology
4. Define strategy for the implementation of the core and enabling technologies
5. Market information - scope of the technology
6. Business justification for project

Question…What and When?

- This template appears to require a lot of assessment work…when is this done?
  - We are not looking for everything at once
  - In the proposal phase an outline should be provided that includes ideas for potential future business and market opportunities
  - The proposal must indicate a separation between the core and enabling technologies, and the final application(s)
  - At each review stage, an update should be provided indicating what has been done to expand the scope of the technology, and the technology fit to other areas
  - The final project review report must include the required market information plus a description of how the technology can be applied in other areas of application

Outline of How Template is Applied



Examples from Current Projects

Two examples have been selected from the current projects to illustrate how template may be used.

- Both projects involve technologies that are being used elsewhere in other OIT projects:

- ***On-line Laser-Ultrasonic Measurement System (Timken project)***
- ***In Situ, Real-Time Measurement of Melt Constituents of Aluminum, Glass and Steel (ERC LIBS project)***

Summary of project

1. Indicate target industry
2. Define need in target industry
3. Outline technology to meet need
4. Indicate core and enabling technologies
5. Intended target applications – main and alternative, and possibilities for spin-off

Laser Ultrasonic Project – Technologies and Applications

- There are currently two other OIT projects involving Laser Ultrasonics:
  - Steel: Non-destructive mechanical properties measurement using laser ultrasonics
  - Forest Products: Contactless real-time monitoring of paper mechanical behavior during papermaking
- The presence of other projects implies cross-cutting capabilities
- What other potential applications exist?

LIBS PROJECT – Molten Metals & Glass: Technologies and Applications

- This project has tremendous cross-cutting potential…the title suggests cross-cutting…which is good
- There are already four other OIT projects which tend to imply more cross-cutting possibilities:
  - Mining: Mine compatible laser analysis instrument for ore grading
  - Forest Products: Laser sensors for on-line monitoring of carry-over in recovery boilers (particulate analysis)
  - Glass: Monitoring and control of alkali volatilization and batch carryover…(particulate analysis)
  - Glass: Measurement and control of glass feedstocks

Define core technology

- Basic sensor technology
- Underlying technical principles
- Enabling technologies
- Sensor construction
- Sensor interfacing
  - Physical
  - Communications
- Sensor implementation
  - Target application
  - Alternative applications

Indicate Applications of Core and Enabling Technologies

- The target application
  - How the sensor works
  - Information provided
  - Interpretation of data
  - Interferences
  - General applicability (to specific application)
- Need to think “Out of the Box”
- Alternative applications (same industry segment)
  - Overview…information provided and ease of adaptation
  - Example applications
- Crosscutting applications (other industry segments)
  - Overview…information provided and ease of adaptation
  - Example applications

Question – Core Technology Development…what and when?

- Is development work carried out independently from the application?
  - Not necessarily…it is assumed that the proposer has already done a large amount of work on the core technology
  - If work needs to be done on the core technology then it is important to indicate what is generic and what is specific relative to the proposal application
  - The work focus throughout the project should be on the application, however, attention must be given to the ability to adapt the technology to other applications

Laser Ultrasonic Project – Core and Enabling Technologies

- Optical fiber-based laser delivery – used of pulsed doubled Nd:YAG laser
  - “Excitation” laser…”pings” the surface
- Laser-based velocimetry – laser based sensing system
  - Pulse detection and measurement system
  - Use of opto-electronics
- Enhanced signal analysis to extract signal from noise
  - Enabling technology
  - Makes the system work
- All three make “sensor” work

LIBS Project – Molten Metals & Glass: Core & Enabling Technologies

- Optical fiber-based laser delivery – used of pulsed laser
  - “Excitation” laser…”vaporizes” the surface
- Fiber-optic probe for laser delivery and optical signal collection
  - Inserted into alien environment
  - Optics and materials selection
- UV Spectrometer system
  - High resolution…

  how high does it have to be? What is available
- Data acquisition and signal measurement
  - System calibration

Define strategy for the implementation of the technology

- Target application
  - Current state of technology
  - Development of prototype
  - Development of fully-functioning sensor
  - Implementation of sensor in target application
  - Deployment of technology
- Application to alternative and crosscutting applications
  - How technology works for other applications
  - Ease of adaptation
  - Strategy for adaptation

Laser Ultrasonic and LIBS Projects: Food for Thought

- Cross-cutting should extend between projects…some food for thought…
  - Fundamental…Both techniques perturb a surface by a pulsed laser
  - Both techniques use optical fiber delivery systems
  - Both techniques require signal extraction
    - The laser ultrasonic project extracts signal from noise
    - LIBS can give rise to noisy data…can it benefit from the same type of data extraction?

Laser Ultrasonic Project – Details

- Project also has indicated other technology developments…
  - Feature extraction…factors influencing eccentricity?
- Pulsed laser system…
  - Power requirements?
  - Laser size and costs?
  - What would it take for other applications?
- Laser detection system…
  - Does it work for other media/surfaces?
  - How different would it be for paper?
- Data extraction…
  - Ability to extract data from noise is fundamental to most sensor measurements
  - Is the current method measurement specific?
  - What does it take to extend to other applications?

LIBS Project – Details

- Pulsed laser system…
  - What are the power requirements?
  - Is this applicable to other surfaces?
  - Laser size and costs?
- Sample probe…
  - Use of optics for harsh environments – standard requirement for process
  - Selection of materials for harsh environments
- Spectrometer…
  - How different is this from that used in other applications?
  - Have low cost systems been applied?
- Calibration…
  - Calibration is usually fundamental…
  - What is different and how can it be adapted?
- What does it take to adapt to other applications?

Laser Ultrasonic and LIBS Projects: Technical Considerations

- There are other applications of Laser Ultrasonics…what does it take to adapt the technology?
  - How different are the paper applications?
  - How material specific is the current application?
  - Can laser-based velocimetry be made more universal?
  - Can the data extraction method be “canned”…that is put into an ASIC (Applications Specific IC) for other applications?
- LIBS has a great number of potential process applications…what does it take to adapt the current system?
  - Can it be made portable?
  - Can it be applied to both liquids and solids?
  - Can the probe technology be used elsewhere?

Market information - scope of the technology

- Target industry
  - Requirement for technology
  - Need filled by technology
  - Benefits gained over existing technologies
  - Size of market for target application
  - Other applications in target industry
- Alternative industry segments
  - Benefits gained over existing technologies
  - Fit and ease of implementation
  - Competing technologies

Business justification for project

- Direct benefits to target industry, including energy savings
  - Size of market and business opportunity
  - Cost of R&D and final implementation
  - Cost to end-user and cost of ownership
  - Does it meet the needs? Does it save energy?
  - How does it rate with competing technologies?
- Benefits to other industry segments
  - Can it be applied cost-effectively?
  - Is the cost of adaptation less than the cost of development?
  - Is the end-use application realistic? Is it competitive?
- Estimate of total business opportunity and consolidated energy savings
  - Target industry segment
  - Other industry segments
  - Total…all industries

The Differences…a Rigid Structure Forcing Diversity

- The template forces a development path and differs from traditional OIT projects by requiring:
  - A crosscutting technology - demonstrated to be applicable to more than one defined industry.
  - Initial focus on the technology aspects - the “engine” and enabling technologies
  - The technologies should be adaptable outside of the target application
  - A path to the adaptation of the technology to other applications is required
  - Lip service to other applications is unacceptable.
  - An understanding of other applications and an adaptation path to other applications is required
  - Marketing and business models to demonstrate an understanding of other industry needs.

Conclusions

- Sensor technologies must be cross-cutting by design and not by accident or afterthought
- Need to think "Out of the Box"
- Need to understand the proposed technology in other contexts
- Need to appreciate what it takes to adapt technology to other applications and industries
- Be realistic and understand the financial implications
  - R&D costs and cost of implementation
  - Is the final cost acceptable for target application?
  - Can the technology be cost effective elsewhere?
  - What does it take to make it cross-cutting?

The Development of a NIR Sensing Device for the Monitoring Liquors in Wood Pulp Digestion Processes

A Worked Example of Applying the Template

Summary of project - Example

- Indicate target industry
  - Forest Products…pulp and paper industry
- Define need in target industry
  - Better control of digesters…reduction in energy usage
- Outline technology to meet need
  - NIR modeling technique to monitor liquor composition in real-time
- Indicate core technology
  - Development of a novel miniature sensing device operating in the short-wave and mid-wave NIR
- Intended target applications – main and alternative
  - Forest: Digester liquors, pulp composition, paper web, etc.
  - Petroleum: Refinery and blending control, also petrochem
  - Chemicals: process and quality control

Define core technology - Example

- Basic sensor technology
  - Micro-engineered array device with integrated wavelength sorter
- Underlying technical principles
  - NIR (800 to 2300 nm) absorption and emission measurements. Wavelength selection by thin film optical filters
- Sensor construction
  - 2-D or 3-D array with bonded/integrated filter mosaic and integrated microelectronics
- Sensor interfacing
  - Waveguide, micro-optics or fiber-optics
  - Electronics output to dedicated DSP-controlled system
- Sensor implementation
  - Target: Requires special cells and sampling system
  - Others: Requires reflectance head and optics

Indicate Applications of Technology - Example

- The target application
  - Measures liquor composition by NIR absorption
  - Provides concentrations of key components
  - Chemometrics modeling provides reaction profile
  - pH and temperature effects need to be handled
  - May be used for Kraft and acid-based digestions
- Alternative applications (same industry segment)
  - With reflectance sampling can monitor pulp/paper production
  - Example applications: wood chips, refined pulp, paper
- Crosscutting applications (other industry segments)
  - With specialized sampling systems and customized optics the system can be adapted to other processes
  - Examples: refinery streams/optimization, polyolefin production, raw material screening, specialized chemical production, product dryers, etc.

Define strategy for the implementation - Example

- Target application
  - Current: NIR measurements are made with large expensive instruments…cost prohibitive for broad-based implementation
  - Prototype: production of small-scale device including optics and electronics
  - Development: Plan for scaling up to device-level production and include all interfacing electronics and optics
  - Implementation: Design sampling system for side-stream measurements
  - Deployment: Provide total system with control software
- Application to alternative and crosscutting applications
  - Other applications: composition monitoring and inferential measurements
  - Adaptation: Develop alternative interfaces
  - Strategy: Refinery and pharma target markets

Market information - scope of the technology - Example

- Target industry
  - Requirement: measure reaction rates to optimize production
  - Need filled by technology: real-time measurement of composition
  - Benefits: more information that T/P/F measurements, more accurate assessment of reaction completion
  - Size of market: North American pulp and paper industry, $XXX million
  - Other applications: wood chips, refined pulp, paper webs…optimized production, reduction in waste and energy consumption

Alternative industry segments

- Benefits; reduced size and cost over existing systems
- Ease of implementation: Varies, mainly optics
- Competing technologies: large-scale instruments

Business justification for project - Example

- Direct benefits to target industry, including energy savings
  - **Size: $XXX million current, $YYY million other applications**
  - **Cost of R&D and final implementation: $2.5 million**
  - **Cost to end-user and cost of ownership: $10K/unit, $1K/year**
  - **Meet the needs? Save energy?: optimizes production, 20% less energy**
  - **Rated with competing technologies?: 80% less expensive**
- Benefits to other industry segments
  - **Other areas of application: Replaces expensive instruments**
  - **Cost of adaptation: <$250K/application**
  - **Realistic? Competitive? Yes, allows for broad implementation**
- Estimate of total business opportunity and consolidated energy savings
  - **Target: $XXX M + $YYY M and 20% energy savings**
  - **Other industries: Application dependent**
  - **Total: $ZZZ M and 10 – 40% energy savings**